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Salvage and Thinning Operations in Second-Growth Ponderosa Pine Stands

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RESEARCH SUMMARY

Management of small-diameter (less than 9 inches diameter at breast height) timber has long been a major problem. Costs of operating conventional harvesting equipment in these stands have generally exceeded the value of the recovered products. In addition, the equipment has often irreparably damaged residual trees. The Northern Rocky Mountain area has many thousands of acres in need of thinning, and the utilization of these trees would enhance the area's present and future timber supply.

This report describes and discusses a harvesting system made up of commercially available equipment and modified farm tractors that has been successfully used to salvage and thin second-growth ponderosa pine stands. Commercial equipment consisted of feller-bunchers, a skidder, and a chipper. Farm tractors were equipped with grapples and metal reinforcings to adapt them to forest use.

Two studies made in the same general area are described, as well as procedures for recovering multiple products. Hog fuel, stud logs, saw logs, house logs, fenceposts, and pulp chips were the products evaluated. Economic analyses indicate that if suitable markets are available within a reasonable distance wood can be harvested in these small-size tree stands at a profit.

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INTRODUCTION

Two often-neglected wood resources are timber removed in precommercial thinnings and postharvest logging residue, consisting of branches, tops, and broken pieces.

The small log resource is vast. In Idaho and Montana, about 30 billion ft^3 of wood is in trees 5.0 to 8.9 inches (12.7 to 22.6 cm) diameter breast height (d.b.h.). Detailed data are available (Troutt 1979) for small-diameter lodgepole pine (*Pinus contorta* var. *latifolia* Dougl.) stands, which make up the largest part of this resource. The information should be generally applicable for all species in this size class, including ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.).

In lodgepole stands, through one rotation, about 65 percent of the stems are in excess of growing stock needs. Many of these could be removed as small logs. Removal would increase the total volume from any given stand by as much as 30 percent during each rotation. In addition, rotation length for lodgepole stands on average sites could be reduced from 100 to about 80 years if all thinnings were accomplished in a timely manner.

In recent years, considerable research has been devoted to inventorying, describing, and evaluating potential uses for postharvest residue. About 10,000 acres (4 050 ha) in the Northern Region of the Forest Service are clearcut annually, and many tons of residue are generated on each acre. Historically, the cost of collecting and transporting residue has made its use uneconomical, and it was burned on the site. However, innovative logging and timber sale methods now are being used to concentrate much of the logging debris at the roadside.

Timber supplies obviously would be enhanced if small-diameter trees and logging residues were better utilized. Landowners would realize a number of benefits, including (1) greater spacing and faster growth for residual crop trees, (2) removal of insect-infested trees and slash that should reduce insect populations and thus future tree mortality, (3) improvement of stand esthetics, (4) reduction of potential fire hazards, and (5) more open stands that provide easier access for future salvage, if necessary, and improved forage growth for livestock and wildlife.

To obtain additional information on utilization of small-diameter trees and logging residues, two studies were made of various harvesting systems applied in ponderosa pine stands. The studies were made in the same area, and many of the cooperators, personnel, and pieces of machinery were the same. One study (study 1) was made in January 1977. The second, more detailed study (study 2) began in September 1980 and lasted 6 months. Results of the studies are discussed separately in this report.

STUDY AREA DESCRIPTION

The study area was located on privately owned land in the Blackfoot River valley about 40 miles (67 km) northeast of Missoula, Mont. (fig. 1). The terrain is gently rolling with slopes averaging less than 10 percent.

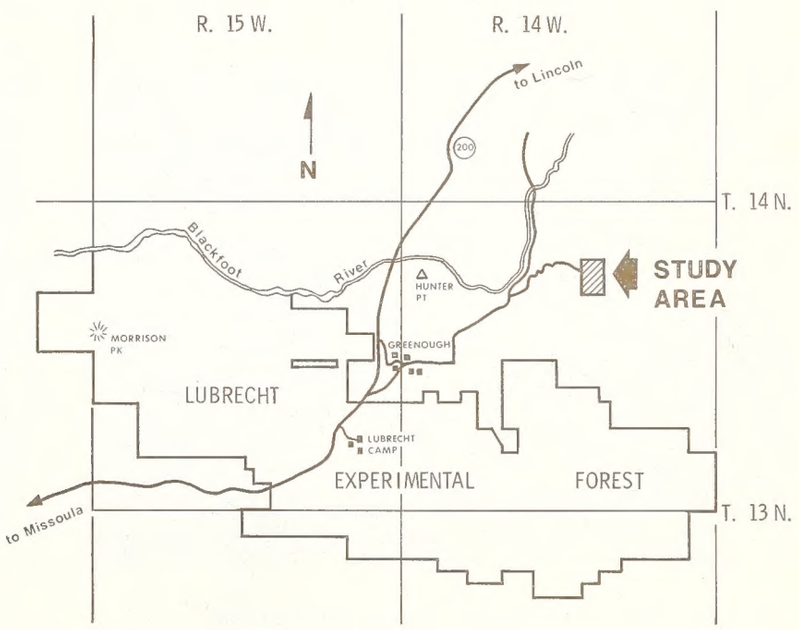

Figure 1.—Map of Missoula vicinity showing the location of the study area.

The young ponderosa pine stands were established naturally following logging between 1885 and 1915. The trees are about 80 years old and the average d.b.h. ranges between 8 and 10 inches (20.3 and 25.4 cm). Most of these second-growth stands are overstocked, with basal areas in excess of 150 ft^2 (13.94 m^2) per acre.

An outbreak of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) started in the area about 1972. Since that time the insect has attacked and killed a large number of trees of various diameters. The infested area, covering about 2,000 acres (809.4 ha), contains numerous patches of dead trees ranging from 1 to 10 acres (0.4 to 4.05 ha) in size.

Cutting in these stands has had several objectives: (1) to remove and utilize the dead trees; (2) to remove green trees considered to be attacked by the insects, thereby controlling, to a certain extent, the insect population; and (3) to reduce the basal area to about 90 ft^2 (8.3 m^2) or less per acre, a more satisfactory level for growth and prevention of insect attack. Other benefits included easier re-entry for salvage and harvesting and improved forage production for grazing.

STUDY 1

Increasing demand for wood products, concurrent with decreasing sawtimber supplies, is requiring the processing of smaller trees. Relatively high costs of harvesting small trees using conventional equipment have made operators hesitant to work in such stands. The objective of this study was to develop information on various systems that might be applicable to young, second-growth timber. Two groups of problems—forest management and harvesting—were addressed.

Some aspects of the forest management problem included: sanitation cutting, thinning, postharvest cleanup, residual tree response, and regeneration. Some harvesting facets examined were: felling and skidding equipment, skidding methods, log-making site, and slash disposal method and location.

Equipment used in the study consisted of gasoline-powered chain saws, a Melroe Bobcat (Model 1075) feller buncher (fig. 2), a rubber-tired Allis Chalmers farm tractor (Model 180) equipped with a rear-mounted homemade grapple, a John Deere rubber-tired skidder (Model 540) equipped with chokers (fig. 3), a Farmhand tractor with a hydraulic lift fork, and a Morbark chipper (Model 22).

Figure 3.—Farm tractor with homemade grapple attached.

Cutting Units

Four 2.5-acre (1.0-ha) units were used in the study. The detailed description of the procedure used on each study unit is as follows:

Unit 1.—On this unit all trees over 1 inch (2.5 cm) that showed signs of insect attack were felled and removed from the stand; healthy trees were not cut. The feller-buncher was used to shear (fig. 4) and group the trees for skidding. Trees too large for the shear were felled with a powersaw. Whole trees were grapple skidded to the landing where they were limbed and bucked into logs and fenceposts. Posts were made from those trees too small for stud logs and from tops between 6 and 3 inches (15.2 and 7.6 cm) in diameter. Saw logs were 33 ft (10.1 m) long. Unusable tops, branches, and small unmerchantable trees were chipped at the landing.

Unit 2.—This unit was logged conventionally. Powersaws were used to fell the trees, which were choker skidded. One skidder was used. Again, whole trees were moved to the landing where limbing and bucking took place. As in unit I, saw logs, stud logs, and fenceposts were cut at the landing and the unusable tops and branches were chipped. The minimum d.b.h. of the felled trees was 9 inches (22.9 cm).

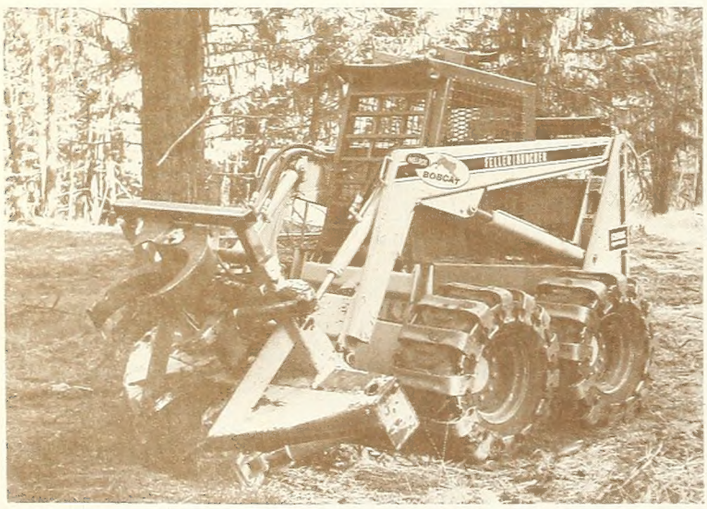

Figure 2.—Shearing head on the Melroe feller-buncher.

Figure 4.—Sheared tree being lowered to the ground.

Unit 3.—All trees cut on this unit had a minimum d.b.h. of 9 inches (22.9 cm). Most trees were sheared using the feller-buncher. Trees too large for the shearing head, including 25 green trees, were felled with a powersaw by the machine operator. One skidder was used full-time, and a second, operated by a member of the landing crew, was used as needed. Entire trees were skidded by the grapple-equipped farm tractor to the landing where only saw logs were cut. The minimum top diameter inside bark (d.i.b.) was 6 inches (15.2 cm). The residue—branches and tops—was burned at the landing as it accumulated.

Unit 4.—This unit had essentially the same utilization standards as unit III. Minimum d.b.h. of the felled trees was 9 inches (22.9 cm). The trees on this unit were felled with a powersaw, limbed, and bucked at the stump with preferred log lengths of 26.5 ft (8.1 m) or 17.3 ft (5.3 m). The logging residue was piled and burned in the stand. The skidder with chokers was used to move the logs to the landing.

On units I and III, the feller-buncher operator was the primary skidder operator, did the powersaw felling, and was crew supervisor. The landing crew was made up of three or four persons. The sawyer did the limbing and bucking; the other crewmembers assisted with the limbing and bucking, did the skidding and decking of logs and fenceposts, and moved the residue to the chipper or burn pile. On units II and IV, a one- or two-man crew was used. One man did the powersaw felling, limbing, and bucking with some help cutting posts at the landing. The other crewmember operated the skidder.

The unit procedures are summarized in table 1.

Results and Discussion

The small size of the study units, 2.5 acres (1 ha), precluded continuous operation of all the machines. The feller-buncher completely felled and bunched the trees on one unit in less than 6 hours and the work on units I and III required less than 1.5 days. However, more than 2 days were needed to skid the trees on these units.

The tree felling data are presented in table 2. As would be expected, use of the feller-buncher was much faster than use of powersaws. The smallest number of trees was cut on unit III, which also had the greatest production rate.

Table 1.—Summary of the procedures and utilization standards for the four study units

Item	Unit I	Unit II	Unit III	Unit IV
Objective	Sanitation salvage	Thinning	Saw log removal	Saw log removal
Prescription	Cut all infested trees	Leave basal area 110 ft²	Cut all infested trees	Leave basal area 110 ft²
Thinning alternative	Precommercial	Commercial	Commercial	Commercial
Felling	Shear	Powersaw	Shear	Powersaw
Limb and buck	Landing	Landing	Landing	Stump
Skid	Grapple	Choker	Grapple	Choker
Residue treatment	Chip	Chip	Burn at landing	Burn at stump
No. in crew	3	1,2	3,4	1,2
		UTILIZATION		
Size skidded	Full tree	Full tree	Full tree	Log length
Min. d.b.h.	1″ (2.5 cm)	9″ (22.9 cm)	9″ (22.9 cm)	9″ (22.9 cm)
Top d.i.b.	3″ (7.6 cm)	3″ (7.6 cm)	6″ (15.1 cm)	6″ (15.1 cm)
Products	Saw logs Posts Chips	Saw logs Posts Chips	Saw logs	Saw logs

Table 2.—Tree felling production rates on the four study units using the feller-buncher (shear) and powersaws

Item	Unit I	Unit II	Unit III	Unit IV
Method	Shear	Powersaw	Shear	Powersaw
Hours per unit	4.85	11.75	[1]2.65	8.26
Hours per acre	1.94	4.70	1.06	3.30
Trees per hour	88	38	69	40

[1]Does not include time required to fell 25 trees using the powersaw.

The number of trees taken from units I and II were 345 and 435, respectively. On unit III, 207 saw logs were produced. On this unit, because the skidding tractor did not have a push blade, the Farmhand tractor was used part-time to deck the logs and move the residue into the fire. On unit IV, 339 logs were skidded and decked conventionally at the landing.

The whole tree chipper's heel-boom grapple did not efficiently handle tops and small stems, but the chipper was the only one available. The objective of the chipping operation was to determine chip volume and quality obtainable in this type of operation. Production measures used were lineal feet of input, (tops and small trees) and weight of chip output. Chip production is shown in table 3. Average chip production for units I and II was 11.9 lineal feet/minute, 2.6 green tons/hour, and 0.9 dry unit/hour. This production was less than normal. In other studies, a Morbark Model 12 and a Trelan Model DL-18 had produced 15 and 13.7 units (200 ft^3 each)/hour, respectively.

As a result production data for a Morbark Eager Beaver model were used for cost analyses. This chipper has a lineal feed rate of 64.5 ft/minute, far exceeding the actual production rate of 11.9 ft/minute. The operational cost of the Beaver chipper was $173.76/day, of which $50 was for the machine and $123.76 for labor.

Personnel utilization.—The interchanging of positions by the crewmembers on units I and III caused some minor timekeeping problems. Unaccounted time expressed as a percentage of gross shift time is shown in table 4.

Two observers, one at the landing and one in the woods, were needed to time the skidding on units I and III. Unit III required the most supervisory time.

Potential productivity rates based on the time studies are shown in table 5. The data show that on units I, II, and III, the skidding rate determines the number of trees processed per hour at the landing, and on unit IV the felling rate determines the number of trees limbed and bucked per hour.

The average time and standard deviation for the critical skidding variables are shown in table 6. These data show the relationship between turns per hour, pieces per turn, and pieces per hour. Units I and III had a high number of turns per hour and a low number of pieces per turn due to the speed and low capacity of the grapple skidder. The opposite held for units II and IV, which had few turns per hour but a large number of pieces skidded per turn. As expected, the volume skidded was affected by the number of pieces and the average volume per piece. The largest volume skidded per hour was on unit I; unit II had the smallest volume skidded per hour.

Table 3.—Various measurements of chip production for units I and II

Item	Unit I	Unit II	Sum or average
Gross time (hours)	11.40	13.65	25.05
Lineal feet	9,177	8,660	17,837
Lineal feet/minute	13.47	10.57	11.87
Tons	31.87	32.14	65.01
Tons/hour	2.80	2.35	2.60
Bone dry units	12.3	9.7	22.0
Bone dry units/hour	1.08	0.71	0.88
Cubic feet	938	1,209	2,147
Cubic feet/hour	82.28	88.57	85.70

Table 4.—Unaccounted time by unit as a percent of shift time

Operation	Unit I	Unit II	Unit III	Unit IV
	Percent			
Woods	2	2	2	1
Skidding	4	2	3	2
Landing	2	2	4	1

Table 5.—Potential productivity rates based on time studies of the various logging functions by study unit

Function	Unit I	Unit II	Unit III	Unit IV
	Shear and bunch	*Saw*	*Shear and bunch*	*Saw*
Felling				
Trees/hour	[1] 88	38	[2] 69	40
Limb and buck				
Trees/hour	46	55.7	30.4	46.3
Posts/hour	68	71	—	—
Skid				
Distance (feet)	874	1,195	730	1,032
Turns/hour	11.8	2.7	9.5	2.0
Pieces/hour	31.8	20.3	21.9	20.4

[1]Includes 46 trees felled with saw.
[2]Includes 18 trees felled with saw.

Table 6.—Average times and standard deviation, in parentheses, for the skidding variables on the study units

Variable	Unit I	Unit II	Unit III	Unit IV
	Minutes			
Hook	—	3.5 (1.0)	—	9.3 (2.0)
Unhook	—	.9 (0.5)	—	.5 (0.2)
Travel	3.8 (1.1)	10.3 (3.0)	4.5 (2.2)	15.7 (3.8)
Round trip (turn)	3.8	14.7	4.5	25.5
Delay	.9	3.5	1.8	4.7
Landing	.4	3.7	—	.1
Turns/hour	11.8	2.7	9.5	2.0
Pieces/turn	2.7	7.4	2.3	10.3
Pieces/hour	31.8	20.3	21.9	20.4
Volume/piece (ft^3)[2]	18.4	14.5	20.1	21.2
Volume/hour (ft^3)[2]	585.1	294.3	440.2	432.5

[1]Landing time not recorded as the log handling was done with a machine other than the skidding tractor.
[2]Does not include unmerchantable material to chipper.

Machine operating charges.—The wage overhead charges for the family-type operations used on units I and III were different from the labor overhead for units II and IV. In a family-type operation many overhead charges are omitted. Usual overhead charges, as a percent of direct wages, are:

Overhead charge	Percent
Holidays	4.5
Health and welfare	4.0
Industrial compensation	22.0
Unemployment compensation	6.5
Social security	7.0
Pension	5.0
Vacation	4.0
Total	53.0

In addition, travel time and transportation, not included in this list, may add 20 to 30 percent more cost.

The farm tractors used in skidding and material transport at the landing on units I and III have low capital requirements and a relatively long economic life under normal farming conditions (table 7). Normal life expectancy exceeds 20 years; a useful life of 15 years was used in the cost determination. (The AC 180 tractor was 18 years old and had been used 11 years for seasonal logging.) Additional years of logging would probably shorten a machine's useful life.

Comparison of the system productivities was based on the assumption that logging was continuous, although some machines and personnel were used only part-time. Because of differences between units, a standard unit was used to rate the study systems.

The standard unit had:

Logged volume/acre	2,430 ft³ (10.8 M bd.ft.)
Volume/tree	18.1 ft³
Trees/acre	134
Board ft/ft³ ratio	4.45

Table 7.—Computation of hourly operating costs for the various study machines

Item	Machine					
	John Deere 540C	Farm-hand F10	Allis Chalmers 180	Melroe 1075	Powersaw	
					Woods	Landing
Initial cost ($)	48,000	10,000	21,000	46,000	[1]1,000	1,000
Salvage ($)	6,000	600	5,000	10,000	0	0
Life						
Hours	10,500	20,000	20,000	12,000	1,500	1,500
Years	7	15	15	10	1	1
Average Annual Investment ($)[2]	9,000	913	5,533	11,800	500	500
FIXED COST PER HOUR						
Depreciation	4.00	0.47	0.80	3.00	0.67	0.67
Interest @ 15%	.90	.09	.55	1.18	.05	.05
Taxes @ 3%	.18	.02	.11	.24	.01	.01
Insurance @ 1.5%	.09	.01	.06	.12	.01	.01
Total fixed	5.17	.059	1.52	4.54	0.74	0.74
VARIABLE COST PER HOUR						
Repair and maintenance[3]	3.60	0.42	0.72	2.70	0.60	0.60
Fuel[4]	2.10	.93	1.00	1.20	.30	.30
Lube[5]	1.05	.46	.50	.60	.15	.15
Tires	1.00	.70	1.00	.60	—	—
Subtotal	7.75	2.51	3.22	5.10	1.05	1.05
Wages - direct	7.83	6.00	8.00	8.00	12.50	9.00
indirect	4.07	3.12	4.16	4.16	6.50	4.68
Total variable	19.65	11.63	15.38	17.26	20.05	14.73
Total/hour	24.82	12.22	16.90	21.80	20.79	15.47

[1]Includes spare saw.

[2]Average annual investment = $\frac{\text{initial cost} - \text{salvage value}}{2 \times \text{number of operating hours}}$ + residual value.

[3]Repair and maintenance = 90 percent of depreciation.

[4]Fuel is based on $1 per gallon.

[5]Lube = 50 percent of fuel.

Production comparisons between the standard and study units were made on an hourly basis, thinning on a per-acre basis, and log production on the number of pieces handled or volume produced per hour. Comparisons of production time per acre and per hour are shown in table 8. Unit III required the greatest number of hours per acre, probably because a tractor was underutilized. The other unit systems were very similar in hours per acre required. Unit IV had no landing time because logs were cut at the stumps and only decked at the landing.

Product recovery.—Sanitation-salvage cutting removed 60 percent of the volume on unit III, 75 percent on unit I, and 77 percent of the volume on unit II (table 9). The commercial thinning, unit IV, removed 71.6 percent of the stand. All insect-infested trees were removed from unit I, only commercial sized trees were taken from unit III, and units II and IV were thinned to 110 ft^2 basal area. Logging residue was the cubic volume of material left on the area after the trees or logs had been skidded to the landing.

Table 8.—Production comparisons of man-machine hours per piece and per acre

Operation		Systems			
		I	II	III	IV
Felling	trees/h	88	38	69	40
	hours/acre	1.52	3.53	1.94	3.35
Limb and buck	trees/h	[1]46.0	[1]55.7	30.4	46.3
	hours/acre	[1]2.91	[1]2.41	4.41	2.89
	posts/h	68	71	—	—
	hours/acre	2.03	2.45	—	—
Skid	pieces/h	31.8	20.3	21.9	20.4
	hours/acre	4.21	6.60	6.12	6.57
Landing	pieces/h	34.7	95.2	11.9	NA
	hours/acre	3.86	1.41	11.26	NA
Total	hours/acre	[1]12.50	[1]13.95	23.73	12.81

[1]Does not include post-making operation.

Table 9.—Stand and treatment volumes on a per-acre basis for each of the study units

Item	Unit							
	I		II		III		IV	
	Ft^3	*Percent*	*Ft^3*	*Percent*	*Ft^3*	*Percent*	*Ft^3*	*Percent*
Initial volume	3,378	100.0	3,272	100.0	2,779	100.0	3,703	100.0
Removed	2,540	75.2	2,519	77.0	1,668	60.0	2,650	71.6
Residual volume	672	19.9	384	11.7	985	35.5	703	19.0
Logging residue[1]	167	4.9	369	11.3	126	4.5	350	9.4

[1]Logging residues 1 inch (2.5 cm) or larger in diameter.

Products obtained from the stands were classified as follows:

1. SAW LOG pieces with at least 11.5 inches (29.2 cm) top diameter and 12 ft (3.7 m) long
2. STUD LOG pieces 5.5 to 11.5 inches (14.0 to 29.2 cm) top diameter and 8 ft (2.4 m) long
3. HOUSE LOG pieces 7.0 inches (17.8 cm) top diameter and any length over 12 ft (3.7 m).

To evaluate lumber and chip recovery, the saw logs from units I and III and units II and IV were combined. These logs were processed into ties, studs, and 2 × 3's. Lumber, tie, and chip recovery is shown in table 10. An estimated 8 percent of the green lumber recovery would be trimmed and lost because of checks and splits in the logs and lumber.

House log use was evaluated using a two-truckload sample of dead ponderosa pine logs obtained from a similar area adjacent to the study units. The sample was processed at a sawmill that had produced materials for a log home manufacturer (table 11).

Table 10.—Lumber and chip recovery obtained from two groups[1] of study unit logs

Item	Group 1 saw logs[1]	Group 2 saw logs[1]
Number of logs	473	446
Total log scale volume (bd.ft.)	31,665	24,297
Average log scale volume (bd.ft.)	67	54
Recovery		
Ties (bd.ft.)	7,586	2,990
Rough green lumber (bd.ft.)	25,038	26,410
Total	32,624	29,400
Lumber trim loss (8%)	2,003	2,113
Rough dry lumber (bd.ft.)	23,035	24,297
Chip volume (bone dry unit)	17.0	12.6
Ratio BDU/M bd.ft.	0.52	0.52

[1]Group saw logs were from units I and III; group 2 saw logs were from units II and IV.

Table 11.—House log sample and recovery of products used in log home manufacture

Item				
	SAMPLE LOGS			
Number of logs	278			
Lineal feet	7,851			
Gross bd.ft. log scale	11,950			
Net bd.ft. log scale	11,880			
Gross ft^3 scale	2,685.4			
	PRODUCT RECOVERY			
	Lineal feet	*Bd.ft.*[1]	*Ft^3*	*Percent*
House logs[2]	2,826	11,304	2,540.2	42.5
Rafters	456	1,596	358.7	6.0
Studs	4,488	2,991	672.1	11.2
Posts (7 ft)	238	71	16.0	.3
1 inch × 6 ft	176	88	19.8	.3
2 inches × 4 inches × 7 ft	469	312	70.1	1.2
Total	8,653	16,362	3,676.9	61.3
	RESIDUE			
Cull, chips, sawdust, bark			2,301.4	

[1]Board foot, cubic foot ratio was 4.45.
[2]House logs are 6-inch (15.2-cm) cants.

Fenceposts were cut at the landing from the tops and submerchantable trees of units I and II. The diameters ranged from 3 to 6 inches (7.6 to 15.2 cm). The following list shows post recovery on a per-acre basis:

	Unit I	Unit II
Number of posts	138	174
Volume, cubic feet	100.7	118.0
Volume, cubic meters	2.8	3.3

Tops, branches, and logging residue created at the unit I and II landings were chipped. An evaluation of the chips is shown in table 12. Lineal feet, the total length of stemwood chipped, not including branches and needles, was about 8,500 and 7,700 ft (2 591 and 2 347 m) for units I and II, respectively. Although unit I had about 10 percent more length than unit II, the gross weight of chips was less, probably due to the smaller trees taken from unit I or the higher percentage of green trees removed from unit II.

The density of the chips was affected by the amount of dead and branch wood. The chipped material of unit I was about 17 percent denser than the chipped material of unit II. Overall chip quality was below commercial standards with 35 and 49 percent of the chips unacceptable for pulping. The unbarked stems and the unscreened chips were the major causes for these high percentages, as shown in the following tabulation comparing woods and mill chipping:

	Woods	Mill
	Percent	
Bark content	19	0.7–2.5
Needle content	1	0
Fines content	17	4–10
Oversize content	5	0

A screening operation would have improved chip quality. Net chip recovery was estimated to be 12.3 and 9.6 bone dry units. This estimate was calculated by multiplying the acceptable chip percentage by the total chip weight, correcting for 29 percent moisture content, and dividing by 2,400 pounds (a bone dry unit).

Total product recovery is shown as a materials balance in table 13. The products were distributed according to unit except that saw logs from units I and III and units II and IV were combined as groups 1 and 2, respectively.

Logged volumes ranged from 60 to 77 percent and the residual stand ranged from 12 to 35 percent of the original stand volumes. Logging residues were lowest in units I and III which had 4.9 and 4.5 percent, respectively. Unit II had 11.3 percent residue and unit IV, 9.5 percent. The large amount of residue on unit II was due to choker skidding full trees, which damaged the residual trees and the operator not wanting to bunch and set chokers on the smaller stems.

Saw log recovery was the largest component on unit I, 81 percent; on unit II it was 76 percent. For the two units, the saw logs removed made up about 60 percent of original stand volume. Wood chips were the next largest component—15 percent for unit I and 19 percent for unit II of the volume removed. Approximately 4 percent of the volume was in fenceposts.

Secondary product yield was based on the two groups of saw logs. Approximately 70 percent of the saw log material was made into lumber or ties.

Economic analysis.—Our economic analysis compares production rates and costs for the different logging systems. Fixed and variable costs for the equipment used are included in table 7. The production rates for the four study units are shown in table 14.

Unit I had the lowest cost per piece, followed by units IV, II, and III. High landing costs adversely affected total costs for unit III. The data also show that the feller-buncher is less costly than the powersaw when compared on a trees-cut basis.

Table 12.—Data on chips produced on units I and II

Item	Unit I	Unit II
Lineal feet chipped	8,481	7,698
Gross weight (pounds)[1]	63,740	64,180
Chipped material (ft^3)	938.04	1,209.19
Density (pounds per ft^3)[2]	67.95	58.00
Percent acceptable chips	65.0	50.8
Percent needles	1.0	1.7
Percent bark	18.9	18.8
Percent oversized chips	5.0	5.0
Number of chip units	12.3	9.7

[1]Weight of chipped material in truck.
[2]Determined by dividing gross weight by volume.

Table 13.—Materials balance by logging unit on a per-acre basis

Item	Unit I		Unit II		Unit III		Unit IV	
	Ft³	*Percent*	*Ft³*	*Percent*	*Ft³*	*Percent*	*Ft³*	
Prelogged stand	3,378	100.0	3,272	100.0	2,779	100.0	3,703	100.0
Logged volume	2,540	75.2	2,519	77.0	1,668	60.0	2,650	71.5
Residues[1]	166.7	4.9	368.8	11.3	125.4	4.5	350.5	9.5
Residual stand	671.7	19.9	384.2	11.7	985.2	35.5	702.6	19.0
Logged material primary products								
Chips								
(acceptable)	242	9.5	190	7.5				
(unacceptable)	133	5.2	294	11.7				
Posts	101	4.0	118	4.7				
Saw logs	2,064	81.3	1,917	76.1				
Total	2,540	100.0	2,519	100.0				
	(71.9 m³)		(71.4 m³)					

Saw log recovery[2] secondary products

	Group 1		Group 2	
Lumber	1,043	55.9	1,439	63.0
Railroad ties	328	17.6	162	7.1
Chips	472	25.3	653	28.6
Residues	22	1.2	30	1.3
Total	1,865	100.0	2,284	100.0
	(52.8 m³)		(64.7 m³)	

[1]Does not include prelogging residues, which are negligible.
[2]Based on sample sawmill recovery study, units I and II = group 1 and units II and IV = group 2.

Table 14.—Comparison of tree to deck logging systems for the four study units

	Unit I	Unit II	Unit III	Unit IV
Felling				
Trees per hour	88	38	69	40
Cost per hour	21.80	20.79	21.80	20.79
Cost per tree	.25	.55	.32	.52
Limb and buck				
Trees per hour	46.0	55.7	30.4	46.3
Cost per hour	15.47	15.47	15.47	20.79
Cost per tree	.34	.28	.51	.45
Skid				
Trees per hour	31.8	20.3	21.9	20.4
Cost per hour	16.90	24.82	16.90	24.82
Cost per piece	.53	1.22	.77	1.22
Landing				
Pieces per hour	34.7	95.2	23.8	—
Cost per hour	15.47	15.47	24.38	—
Cost per piece	.45	.16	1.02	—
Post-making				
Posts per hour	68	71		
Cost per hour	15.47	15.47		
Cost per post	.23	.22		
Total Cost Per Piece	1.57	2.21	2.62	2.19
Hours	69.64	76.55	78.55	66.40
M bd.ft.	36.50	62.83	59.83	54.17
Acres	183.18	398.63	472.50	394.96
Hectares	517.53	728.50	863.66	721.91
Cunits	8.66	12.19	14.45	12.08
Meters[1]	11.11	15.64	18.54	15.50

[1]M bd.ft. = 2.36 m³. Chipping costs for units I and II are not included.

Table 15.—Income and cost data for the four study units on a per-acre basis

Item	Unit			
	I	II	III	IV
Gross income	1,552.82	1,565.38	907.55	1,442.26
Cost	183.18	398.16	472.50	394.96
Net income	1,369.64	1,167.22	435.05	1,047.30

Total costs and income.—Prices used to determine income were: $128/M bd.ft. log scale, $12/bone dry unit of pulp chips, and $0.69/fencepost. Cost data for the logging systems on the individual units are shown in table 14, and the income and cost on a per-acre basis in table 15. Hog fuel chips and fenceposts are included in the income for units I and II, as is the production cost of the fenceposts. However, because the chipper was of the wrong capacity, the chipper costs were excessive and are omitted. The data show that units I and II were the most profitable. These units also were left with a suitable stocking of young trees, and no postharvest treatment was necessary.

In addition to the income, other land management benefits were derived from operating in these young stands. Cleaning the stand will make future access easier. Removal of the smaller trees makes additional minerals and growing space available to the residual stand. Also, removal of the insect-infested trees should provide some protection to the crop trees. In addition, opening the stands should increase forage production and permit ready access for timber salvage or harvesting (fig. 5).

Land management consideration.—The unit data also provided information for comparing limbing, bucking, and slash disposal at the landing and the same operations at the stumps. Also, sanitation-salvage cutting could be compared with saw log removal.

Limbing and bucking at the landing reduced the skidding cost, especially if the trees contained more than one saw log. Another advantage of whole-tree skidding was reduction of slash in the logged area. Limbing at the stump and skidding tree lengths to the landing for processing eliminates this advantage. In salvage operations, concentration and disposal of the slash is an important insect control measure. If partial cuts are made, the slash may be concentrated in stand clearings before being burned.

Figure 5.—A typical stand after being thinned.

The quantity of logging residue left on an area can be used as a criterion of good or bad harvesting practices. Residue percentages derived from different bases are shown in table 16. The residue percentages of the original and residual stands indicate the need for and degree of slash disposal activities required. The large percentage of residues in unit II resulted from operator carelessness and his expectancy that the residues would be cleared and burned.

Conclusions

The results of this study indicate that thinning and salvage operations in young second-growth ponderosa pine stands can be done at a profit only if a sufficient amount of sawtimber can be removed. Recovery of other products, such as fenceposts and pulp chips, is not great enough to cover operational costs.

Commonly available ranch and farm machinery proved to be well suited for harvesting work in young timber. Farm tractors can be fitted with grapples for whole-tree or log skidding and these machines can also be used to deck logs and pile slash. Properly used, the tractors were economical and efficient, and did a minimum amount of damage to residual trees.

Feller-bunchers were more efficient than chain saws in severing the trees, and grapple skidding was better than choker skidding. Full-tree skidding with processing at the landing did less damage to the stand than log skidding, as fewer stand entries were needed to remove all the small trees. Log making at the landing concentrated the tops and branches so that this material could be made into pulp chips or hog fuel. Tree-length skidding also permitted production of several different products—saw logs, posts, house logs—and concentration of these items at a single location.

Competent, well-trained personnel are required if small timber stands are to be profitably harvested.

Table 16.—Residues by cutting unit as a percentage of original and residual stand volumes and log volumes removed

Item	Cutting unit			
	I	II	III	IV
Percent of original stand	4.9	11.3	4.5	9.5
Percent residual stand	24.8	96.0	12.7	49.9
Percent volume removed	6.6	14.6	7.5	13.2

STUDY 2

A second study, made in the same general area, was started in the fall of 1980 and extended through the winter to the following March. During this interval, 8 areas totaling about 134 acres of second-growth ponderosa pine were sanitized and thinned. Sanitation consisted of removing living and dead trees that showed signs of the presence of insects, holes, or pitch tubes on the stems, and thinning to improve the spacing between residual trees.

Procedure

Experience gained from earlier work in the same ponderosa pine stands was used to determine procedures adopted for this investigation. The selected procedure consisted of three tree-felling phases.

The first phase was to go through the stand with a three- or four-man crew. One crewmember used a chain saw to fell trees less than 5 inches d.b.h. The other crewmembers bunched the trees, butt ends together, for skidding.

The second phase was to use the feller-buncher to cut and pile the trees between 6 and 10 inches in stump-high diameter. A small and a large Melroe Bobcat, Models 825 and 1075, were used. The final phase was to fell with a chain saw the trees too large in diameter for the feller-buncher shear opening.

All trees were skidded with either a John Deere 440 skidder or various farm tractors fitted with rear-mounted, shop-built grapples. Tree lengths only were moved to the landing. At the landing the larger trees were cut into stud and saw logs and decked for later removal. Tops, branches, and smaller trees were chipped in a Morbark Model 12 Chiparvestor, and the fuel chips were discharged into 40-ft flat-bottomed pulp chip van. To utilize the chipper near capacity, the smaller trees were stockpiled in a near-vertical position at the landing (fig. 6). After chipping had started, the stockpiled trees were used to maintain a continuous flow of material to the chipper, supplementing the tops and branches from freshly skidded saw-log-size trees.

Figure 6.— Stockpiling of thinned trees at the landing.

The objective of the study was to determine the productivity and costs of this harvesting system. Productivity was measured by a physical count of trees cut in each of the three felling phases, by sampling the skidded bunches, and by recording the time needed to complete each operation. With the exception of the small hand-felled stems, the diameter at the butt end, d.b.h., length to a 6-inch diameter, and total length were recorded for each tree in the sampled bunch. Butt diameter and total length only were recorded for the small tree sample bunches. Total costs were calculated by using the machine and man-hours and the hourly cost of each. Prorating these costs permitted calculation of individual tree-felling cost and bunch-skidding cost. Chipping cost per unit was determined by recording the time necessary to fill a van of known capacity.

Values recovered from the areas were based on 200-ft^3 hog fuel units blown into the van at $16 each, stud logs at $80/M bd.ft. Scribner log scale, and saw logs at $164/M bd.ft. Scribner log scale. Log prices were for the material decked at the landing.

Results and Discussion

Hourly and daily rates for the different pieces of study equipment are shown in table 17. In addition, a $50 rate per day per man was used in computing the costs of felling, skidding, and processing individual trees as well as per-acre costs. Cost data for the individual study areas are shown in table 18.

As would be expected, per-acre cost for the various operations varied widely, reflecting the different stand and operating conditions. Hand thinning cost per acre ranged from $43.68 to $147.20, and the weighted average cost per acre was $86.12. Machine thinning cost per acre ranged from $7.99 to $87.65, and the weighted average cost was $32.25 per acre. The total skidding cost per acre, for all trees, ranged from $40.18 to $149.14, and the weighted average per-acre cost was $76.72. The total cost of producing chips, stud logs, and saw logs ranged from $102.99 to $498.09 per acre, and the weighted average cost was $166.45 per acre.

Income data and the net return per acre are shown in table 19. The total cost per acre ranged from $185.66 to $814.26. The income per acre from hog fuel ranged from $70.50 to $681.33, with a weighted average income of $219.09 per acre. Stud log income ranged from $33.60 to $468.27 per acre, and the weighted average income was $321.43 per acre. Sawtimber was obtained from five areas and the value of this product ranged from $43.74 to $210.46 per acre, with a weighted average of $150.31 per acre. Total per-acre income ranged from $226.95 to $919.35, and the weighted average income per acre was $648.50. Net return per acre ranged from a loss of $99.77 to a profit of $439.43, with a weighted average return of $308.80 profit.

In general, the value of the hog fuel was at least one-third and as much as 86 percent of the total per-acre costs. Income from the stud logs and saw logs provided most of the profit margin. The two areas that had a net loss per acre produced no saw logs.

Table 17.—Hourly and daily rates for various pieces of equipment used in thinning study

Machine	Cost per hour	Cost per day
	Dollars	
Chip Harvester Model 12[1]	32.00	200.00
John Deere 440 skidder	16.00	100.00
John Deere 2940 4WD tractor	7.50	55.00
Allis Chalmers 180 and Ford 7000 tractors	6.00	40.00
Melroe "Bobkitten" steer skid	6.25	55.00
Melroe Bobcat 1075 feller-buncher	15.00	100.00
Front end loader[2]	6.50	50.00
6x6 flatbed truck	6.50	50.00
Dump truck	3.00	20.00
Stock truck	3.00	20.00
Semi-tractor	13.00	100.00
Crawler tractors	13.00	100.00
Road grader	4.00	30.00
Husky heelboom loader	3.00	25.00
Fifth wheel trailer	1.50	10.00
Semi-trailer, 45 feet	2.25	18.00
Chain Saws	4.00 per day for saw only 10.00 per day for saw, gas, oil, etc.	
AC 2000 tractors	6.75	50.00

[1]Data for the first six machines include all fixed and variable costs, but exclude operator or labor costs.
[2]Data for the other machines do not include fuel, lube, or minor repair costs.

Table 18.—Costs of performing various harvesting operations on the eight study areas

Area	Hand thinning				Machine thinning			Sawtimber		Skidding	Processing (cost/acre)		
	Acres	No. trees	Cost/ stem	Cost/ acre	No. trees	Cost/ stem	Cost/ acre	Volume cut	Cost/ acre	Total cost/acre	Chipping	Stud logs	Saw logs
								M bd.ft.					
Gravel Pit	20.50	8,058	$0.19	$ 74.03	1,580	$0.25	$19.41	17,130	$2.52	$ 97.04	$138.30	$ 20.69	$1.26
Section 34	29.56	6,383	.20	43.68	3,565	.35	42.42	25,670	1.44	103.96	150.71	40.48	4.93
Airstrip A & B	5.35	1,087	.19	79.38	2,079	.22	87.65	—	—	149.14	387.37	110.72	—
Big Chip Pile	7.10	3,550	.19	94.87	325	.43	19.65	—	—	61.44	114.08	37.34	—
Spring Creek	5.00	3,850	.19	147.20	252	.49	24.60	4,610	6.84	85.11	129.60	40.59	9.57
No Name Creek	18.00	12,277	.19	134.56	1,216	.32	21.75	15,140	6.67	80.66	146.25	23.23	9.17
Rifle Range	8.70	6,870	.15	120.83	148	.47	7.99	—	—	56.24	139.66	2.00	—
Crazy Gate	39.20	—	—	—	1,863	.78	37.24	50,000	5.25	40.18	41.33	58.81	2.85
Weighted average cost/acre				86.12			32.25		4.05	76.72	---------$166.45---------		

Table 19.—Per-acre income from the various products for the eight study areas

Area	Acres	Total cost/acre	Income per acre			Total income/ acre	Profit (or loss)/acre
			Chips	Stud logs	Sawtimber		
			Dollars				
Gravel Pit	20.50	353.25	225.00	260.80	138.60	624.40	271.15
Section 34	29.56	387.62	256.80	426.96	143.29	827.05	439.43
Airstrip A & B	5.35	814.26	681.33	238.02	—	919.35	105.09
Big Chip Pile	7.10	327.38	186.60	138.80	—	325.40	(1.98)
Spring Creek	5.00	443.51	215.85	231.20	151.80	598.85	155.34
No Name Creek	18.00	422.29	363.26	159.12	43.74	566.12	143.83
Rifle Range	8.70	326.72	193.35	33.60	—	226.95	(99.77)
Crazy Gate	39.20	185.66	70.50	468.27	210.46	749.23	563.57
Weighted average/acre		339.70	219.09	321.43	150.31	648.50	308.80

Conclusions

Results of the second study indicated that with suitable markets available within a reasonable distance, small-sized trees can be economically harvested and utilized. A three-step system that removed the smallest trees first and the largest trees last proved to be an efficient harvesting method. Grapple skidding with a modified farm tractor that permitted slope decking of the trees at the landing was a cost-effective procedure for operating the chipper near capacity.

The total weighted average cost per acre of felling, skidding, and processing the trees was $339.70. Most of the harvesting cost was covered by the value of the hog fuel, and the value of the saw logs provided a profit margin. The weighted average per-acre income from hog fuel was $219.09, for stud logs $321.43, and for saw logs $150.31. The weighted average total income per acre was $648.50, and the weighted average profit per acre was $308.80.

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Wood from salvage and thinning operations in second-growth stands in western National Forests constitutes a potential resource that may help alleviate present and future timber shortages. This report presents cost information and describes harvesting systems and machines that have satisfactorily and economically operated in such stands.

KEYWORDS: salvage thinning, logging systems, small tree utilization, second-growth timber stands, whole-tree chipping

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